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Performance evaluation of clustering scheme for FANETs based on K-means algorithm and firefly optimization

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ABSTRACT
With increasing development of wireless communication network, Unmanned Aerial Vehicle (UAV) has emerged as a flying platform for wireless communication with efficient coverage, capacity and reliability but UAV as a FANET (Flying Ad-hoc Network) has some communication issues due to mobility of networks that leads to change in topology of network. In this paper we propose a hybridization of Self-organization based clustering scheme (SOCS) with k-means algorithm for cluster formation, cluster management, selection of cluster head and cluster members and use Firefly Optimization for routing mechanism of cluster. In this paper, the evaluation of performance with experimental results obtained has been compared with existing SOCS using Glowworm Swarm Optimization (GSO) in terms of cluster building time, cluster lifetime, energy consumption, probability of delivery success.

Keywords: FANET, cluster, Glowworm Swarm Optimization, Firefly Optimization

1. INTRODUCTION

Unmanned aerial vehicle (UAV) is a most promising technology in modern era of wireless communication [1-2], with the development of 5G network and increasing demand of wireless communication networks. Device-to-Device (D2D) communication [3],[4], ad-hoc networks [6], [10] becomes a need of today's generation. In advance generation it may have possibility that UAV replaces the need of tower and cables, leads to generation of smart city [7] Moreover, to building of its infrastructure is really a time consuming process, needs more manpower resource, its expensive and has many drawbacks after all of these, cross talks, call drops are common problems faced in terrestrial networks. UAVs are mobile, reliable, flexible, cost-effective and on-demand solution of wireless communication network [25]. These can also support connectivity of other terrestrial and cellular network [17]-[19] internet of things (IOT) [20]-[24] can be easily possible with the large scale power transmitting of UAV. This application of UAV made it to use in various fields that is in military, navigation, surveillance, broader supervision, medical supply, control, search and rescue operations, inspection of hazardous events, disaster management, monitoring, relay network, automation, remote sensing, telecommunication [6-7], [9], [11]-[16]. In case of emergency when all networks fails then UAV is only option to rescue people from situation and supply emergency services.

UAVs commonly known as drones stands for Dynamic Remotely Operated Navigation Equipment. Network of UAV called FANET known as Flying Ad-hoc Network [8] FANET enables UAVs to communicate with each other and ground control station (GCS), due to mobile nature of UAV and continuously changing topology of UAV creates a network issue [26]. Clustering is solution of this problem [27]. It is a method to divide the network into groups called clusters. Clustering consists of cluster head (CH) and cluster members (CMs) in each cluster [28] Cluster head (CH) is responsible for routing and operation of each cluster that is in case of any nonworking and dead node it is a responsibility of cluster head to manage an operation whether to connect or to disconnect a node is completely a charge of cluster head without effecting operation of cluster in anyways, for transmission of data from cluster to other, cluster head plays a major role for efficient communication that is, data is to be send from source cluster member (CM) to its respective cluster head (CH) of that cluster and then transmit that data packet to destination cluster head (CH) to destination cluster member (CM) that is how transmission of FANET and its inter and intra cluster operation takes place [29] cluster head is important parameter of clustering, It has a responsibility to manage whole cluster. It's selection is based on various parameters as fitness function, residual energy, energy utilization, number of neighbors, position of node, life of UAV, possibility of maximum success rate, maintenance, control over other nodes, optimization.

Optimization is a technique to find the best solution of any computational problem. In this paper we will deal with nature's observation and its solutions to deal with our evolved clustering issues. Here, we first test and then implement our solution for high performances [30]. There are multiple optimizations for clustering in FANET as Ant Colony Optimization (ACO), Glowworm Swarm Optimization (GWO), Firefly Optimization (FO) many others. Ant colony optimization (ACO) is inspired from Ant behavior, ant leave chemicals called pheromones, when walked search for food for the assistance of other ants and they gradually find the shortest distance of their path [30] In Glow worm Swarm Optimization (GSO) clustering scheme of FANET, it is inspired by the glowworm behavior, Each glowworm carries a luminescence called luciferin, which decides the position and brightness of glowworm, lesser brighter glowworm attract towards higher brighter glowworm within decision boundary, and update its brightness and position, this iteration goes on till solution does not reach a optimal value [26].

In this paper we will deal with Firefly optimization algorithm, this algorithm has a unconstrained functions in higher dimensions unlike GSO [31]. The contributions of the paper are:

We propose a new clustering mechanism in FANET using hybridization of SOCS with k-means

We propose a cluster formation selection of cluster head (CH), cluster members(CMs) and routing mechanism between nodes.

We propose novel optimization technique for routing using firefly Optimization.

Evaluation of QOS parameters & compare with existing work of SOCS for FANET using Glowworm Swarm Optimization in terms of energy consumption, cluster building time, cluster lifetime and probability of delivery success.

The rest of the paper is tabulated as: section 2 explains about SOCS hybridizes with k-means algorithm model cluster formation, cluster management and routing between nodes. Section 3 explains optimized technique of routing using firefly optimization. Section 4 provides explanation of evaluation of FANET using k-means and Firefly optimization. Section 5 concludes the paper.

2. CLUSTERING USING K- MEANS ALGORITHM

k-means is simplest and unsupervised clustering algorithm. This algorithm is a method to group data into clusters on the basis of Euclidean distance between data members and centroid [32] Purpose of the algorithm is data member share similar characteristics cluster together.

This procedure involves a few steps as follows:-

From the data set randomly select k clusters centers called centroid of cluster.
Calculate the Euclidean distance between selected centroids with each data member.
Distance is calculated by following equation:-

$$\mathrm{Dis}(p_k, q_j) = \sqrt{\sum_{i=1}^{d}\left(p_{ki} - q_{ji}\right)^2} \qquad (1)$$

Where, p_k denotes k^{th} data member and q_j denotes centroid of cluster j, i denotes number of data members.
Calculate the mean of updated data members of each cluster.
If calculated mean is same that of centroid of cluster then iteration stops and centroid gets updated.
Equation to calculate update centroid of cluster:-

$$Z_j = \frac{1}{n_j}\left[\sum_{\forall p_{k \in c_j}} p_k\right] \qquad (2)$$

Where, n_j denotes number of data members in cluster j and c_j is subset to form cluster j.

If difference between mean and centroid is there, then number of iteration continues till there is little change in centroid after each iteration or no change.

In similar way cluster head and cluster members are elected in each cluster of FANET structure from number of UAVs. Similarity between each data member is classified on the basis of Euclidean distance between them.

Cluster formation using SOCS and K- MEANS Algorithm

Cluster formation using SOCS and k-means algorithm involves management of cluster and selection of cluster head (CH), cluster members (CMs) using above mentioned steps of k-means and also connectivity of cluster heads Ground Control Station (GCS) is to be mentioned in algorithm

ALGORITHM 1 Cluster formation in SOCS and k-means algorithm

```
Initialize parameters, number of nodes, area, number of cluster head:
Initialize and select color of each cluster nodes, connecting lines:

DO (specify every node of cluster)
While (select and specify CH)
For (connect node with nearest cluster head with k-means clustering)
    Specify GCS location
            For (connect GCS with every GCS)
        Locate source node position
            Set radius node position
                Set radius of GCS
Check (Distance of GCS and source node)
If (distance of source node is less than set radius of BS)
then ( update connection of GCS and source node)

end
end
end
```

In this algorithm, initialize parameters number of nodes, area, number of cluster heads. Specify every node with unique name say, U_1, U_2--------U_n. Using k-means algorithm form clusters and specify cluster heads for every cluster say, CH_1, CH_2-----CH_n. Connect CHs with every node of cluster called cluster members (CMs). Specify GCS location (in middle of area) connect every CH with GCS. Locate the source node position and set radius of GCS. If distance between of source node is less than GCS radius then update connection between them.

Routing Mechanism using K-Means

After clustering using k-means algorithm, routing mechanism between nodes is to be performed. For this source node is to be specified and using k-means algorithm path is traced to reach data from source end to destination end. various intermediate nodes perform task to reach data from source to destination, that selection of intermediate nodes and process of transmission of data using k-means is explained in algorithm:-

ALGORITHM 2 Routing in k-means

```
RREP <= Request to reply
Check point<= no of times check nodes to reach destination
Destfound<= To specify destination found

Check distance of source node with every node in its specified range to reach destination
Specify number of check points

If (RREP==1)    // transmitted node has connection with destination
 Update the specific node
again,
    check(every node in range to reach destination)
  If (packet reaches destination)
     then    Destfound =1;
  else
        check till reaches checkpoint
end
  for(connect all node from source to destination end)
 for(feed the sequence of intermediate node connection)
end
end
```

In this algorithm, specify a source node and check distance of source node in its specified range to reach destination and specify number of check points. When RREP(request to reply) from any nodes comes to be positive then update and transfer data to the node for further transmission then this node again check node in its range to reach destination. This process goes on till data reach its destination. When data reaches its destination then it assigns 1 that signifies it reached. If after specified checkpoints data does manage to reach destination then data dropped and process ends. After data reaches to destination connect all intermediate nodes from source to destination via a path and feed the sequence of the path for further transmission.

Firefly optimization algorithm

Fireflies Algorithm is a inspired from natural phenomena of flashing pattern and behavior of fireflies [32]. These are winged insects that produce a flash called bioluminensce that they use for communication and attracting a prey. In 2008 inspired by this behavior of fireflies Yang introduced an algorithm. Yang inspiring from these activity under assumption made three idealized rules, these are:- Fireflies are unisex,they attract one other regardless of their sex.

Attractiveness between two fireflies is directly proportional to their brightness and inveresly proportional to distance between two fireflies,as distance increases their brightness decreases. Thus, brighter firefly attract the less brighter one but in case both have same brightness then this will lead to random movement of both the fireflies. Brightness of fireflies is determined by landscape of the objective functions [33].

Based on above idealogy, firefly is classified into three parameters:

Attractiveness :- This signify light intensity between two fireflies. It is defined with exponential function.

Randomization :- when attractivess i.e above defined parameter set to zero, then fireflies starts random movement that correspondace to randomization parameter. It is deterimened with gaussion distribution function from interval [0,1].

Absorption :- This parameter effects attractiveness parameter from zero to infinity.in case of convergence to infinity movement of GORITHM fireflies happens randomly [30].

For n fireflies, brightness of firefly i is associated with objective function f (x) i.e

$$I = f(x) \qquad (3)$$

It reveals that current position of firefly from the set x_1, x_2_______x_d

Suppose, for two fireflies m and n namely with positions x_m, x_n respectively.Their attraction depends upon their quantity of brightness and some constraints between both of them like absorption of air and square of distance between these two fireflies.

Relative distance between these two fireflies is:-

$$I_{mn}(r_{mn}) = \frac{I_n}{r_{mn}^2} \qquad (4)$$

or

$$I_{mn}(r_{mn}) = I_{mn}e^{-\gamma r2_{mn}} \qquad (5)$$

Where I_{mn} is absolute luminensce of firefly m and firefly n, r_{mn} is distance between both fireflies m and n respectively,γ is light absorption coefficient.

Attraction between fireflies is represented as:-

$$\beta_{mn}(r_{mn}) = \beta_0 e^{-\gamma r_{mn}^2} \qquad (6)$$

β_0 firefly attraction at r = 0, γ is light absorption coefficient, in many applications it is generally taken as [0.01,1.00] [30]

Now firefly n attracted towards firefly m is updated its position by equation:

$$x_n = x_n + \beta_{mn}(r_{mn})(x_m - x_n) + \alpha\varepsilon_n \quad (7)$$

Where,$\beta_{mn}(r_{mn})$ is attraction parameter and $\alpha\varepsilon_n$ is randomization parameter [33].

Firefly optimization using artificial neural network

Artificial Neural Network (ANN) inspired from biological neural network. It is collection of artificial neurons connected by weights that are responsible for transmission of data. These systems are designed for self training, implementing and testing process by their hidden layers.

In firefly optimization ANN is used for optimizing a path for transmission of data by self learning and implementing a path and then analyzing best path for transmission which leads to satisfy cluster parameters and increase efficiency of cluster.

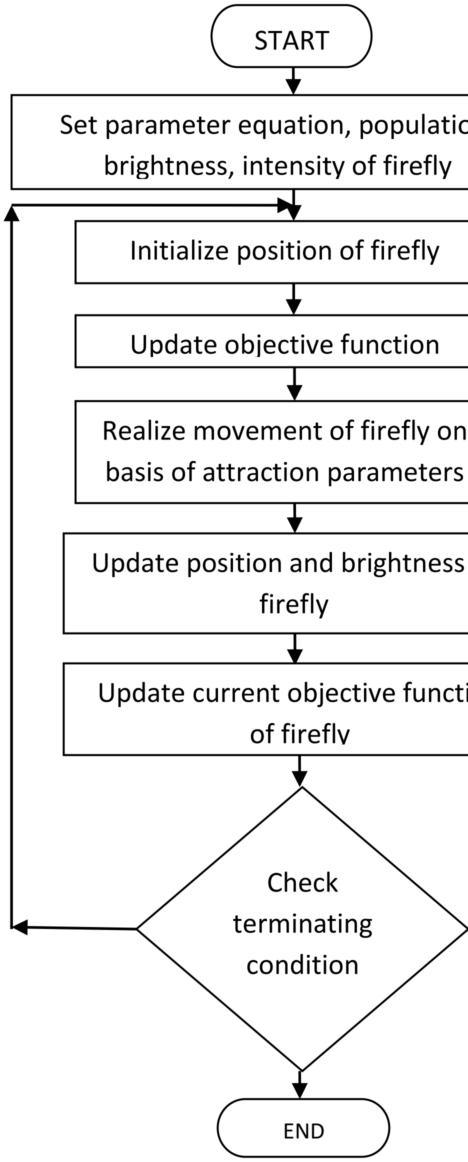

Figure 1 Firefly formation mechanism

ALGORITHM 3 OPTIMIZATION USING FIREFLY

Initialize value of cluster lifetime, energy consumption, cluster building time, number of packets to be delivered.

Initialize the empty list of fail UAV

for (routing from source to destination)

check if (fail UAV~=source node && fail UAV~= Destination node)

then(specify it as fail UAV)

Update and increment list of fail UAV

Update (Transmission path replacing node)

Update parameters for this optimized path

Update (energy consumption, cluster lifetime, building time, probability of delivery success)
Iterate for other nodes.
end

In this algorithm, first of all faulty node is traced and optimization of path using firefly and ANN, for this assigned variables are divided into ratio of memory allocation for training, implementing and testing process. For training maximum memory needs to be allocated as it has to again and again train itself according to variation in its input and optimize a path that leads to increase in cluster lifetime, cluster building time, energy consumption and probability of successful delivery.

3. PERFORMANCE EVALUATION

The simulation software used for performance evaluation and comparison from previous obtained results is MATLAB, on this software cluster formation, management, communication is performed and compared with SOCS using GSO in terms of cluster building time, energy consumption, cluster life time and probability of delivery success. These evaluations are performed on different area sizes, parameters with varying number of UAVs as shown in Table 1.

TABLE 1 Simulation parameters

Parameters	Values Size
Grid Size	1000×1000 m^2, 3000×3000 m^2
Number of UAVs	15, 20, 25, 30, 35
UAVs distance	5m
Transmission Frequency	2.45 GHz
Mobility Model	Reference point mobility model
Simulation Time	120s
Position Exchange Interval	2s
Transmission Range	Dynamic
Receiver Sensitivity	-90dBm
UAV initial energy level	80Wh
Constant bit rate	100kbps

Cluster building time

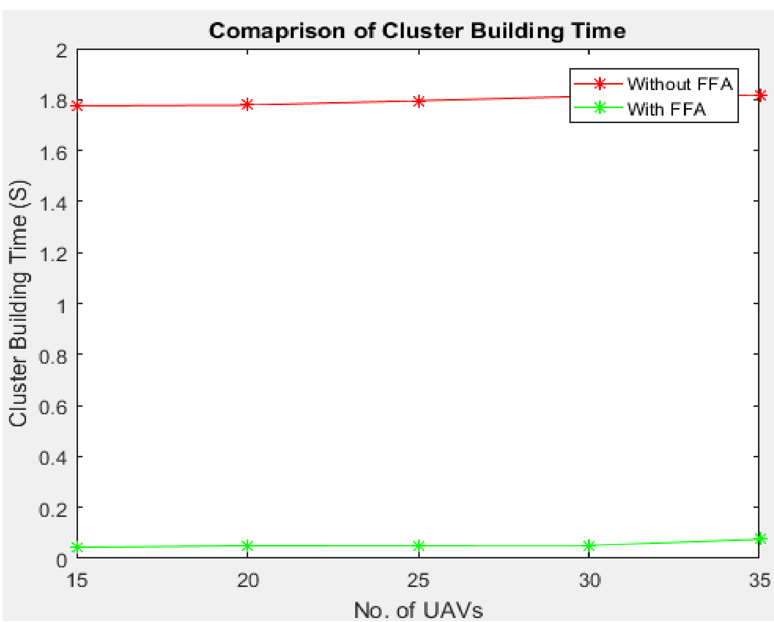

Figure 2 Cluster building time vs no. of UAVs in grid size 1000×1000m^2

Cluster building time is the time taken for cluster formation, selection of CH and its associated CMs, performing input output operations and establishing communication network with other UAVs and GCS [26]. Factors that affect the performance of UAV Increasing number of UAVs in network leads to decrease performance of UAV. Low memory and computation power in UAV also affects cluster building time. If energy consumption in UAV is more then more will be time taken for cluster formation. Results proved in Fig 2 and 3 that it takes less time for cluster formation leads to decrease in delay for route selection results in saving energy of UAV for performing complex computation. So, it can be said that SOCS with k-means algorithm performed better than SOCS using GSO in cluster formation.

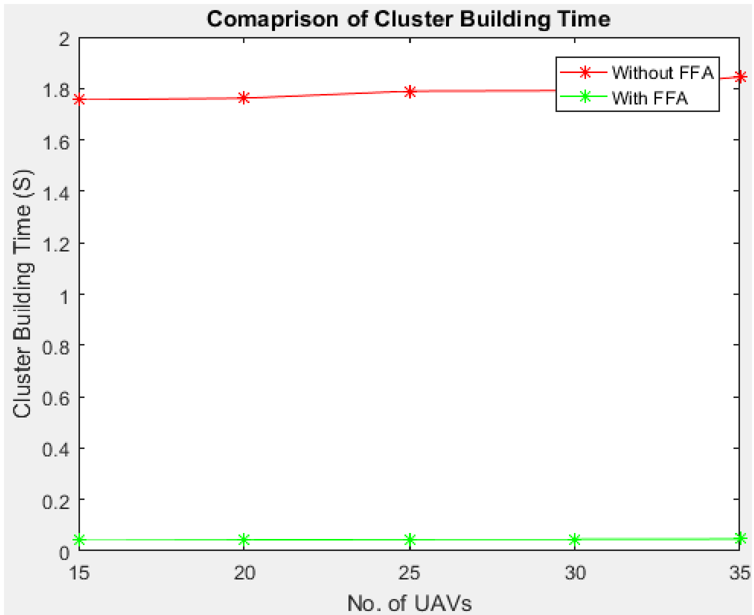

Figure 3 Cluster building time vs no. of UAVs in grid size 3000×3000m²

Energy consumption

Energy is most essential aspect of UAV. It is energy consumption from cluster building to its lifetime for performing all operations of UAV, as for flying, for communication, by sensors (cameras, GPS systems, radar and lightning detector system) that are mounted on UAV for convenience and obtaining received information from UAV. Moreover, major parameters of UAV as route selection, rate of successful packet deliveries, delays in transmission, collisions depends upon node energy. Total energy consumed by UAV is given by following equation:-

$$E_t = E_c + E_f + E_s$$

Where, E_t represents total energy dissipated,E_c represents energy consumed for communication, E_f energy dissipated during flying and E_s is energy consumed by sensors. Energy consumed during communication is due to transmitters, receivers and amplifiers (signal boosters) installed in it. Energy consumed during communication is represented by equation:-

$$E_c = E_t + E_r$$

Where,E_t and E_r represent energy consumed by transmitter and receiver.

$$E_r = E_{tr} \times k$$

$$E_t = E_{tr} \times k + E_a \times k \times D^2$$

Where, E_{tr} represents energy dissipated by running transmitter and receiver, E_a is amplifier energy, k represents bits transmitted by UAV and D represents bits transmitted and received during UAVs communication. We calculated that energy consumption using proposed algorithm is less than energy consumption of UAVs with SOCS using GSO in Fig 4, 5 reasons for less energy consumption is our efficient cluster building parameters and also with increase in number of UAVs leads to more energy consumption.

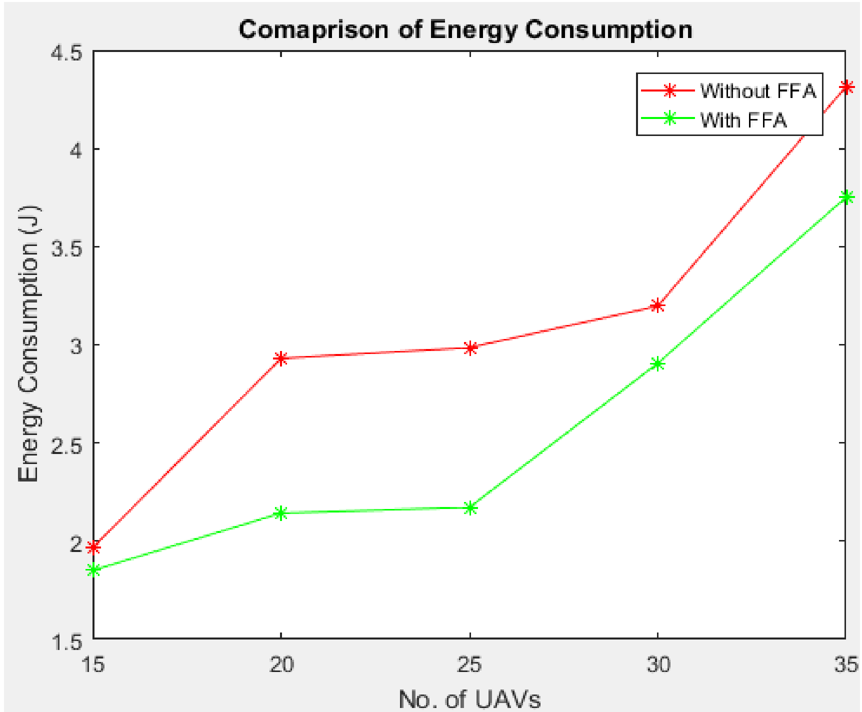

Figure 4 Energy consumption vs no of UAVs in grid size 1000×1000m^2

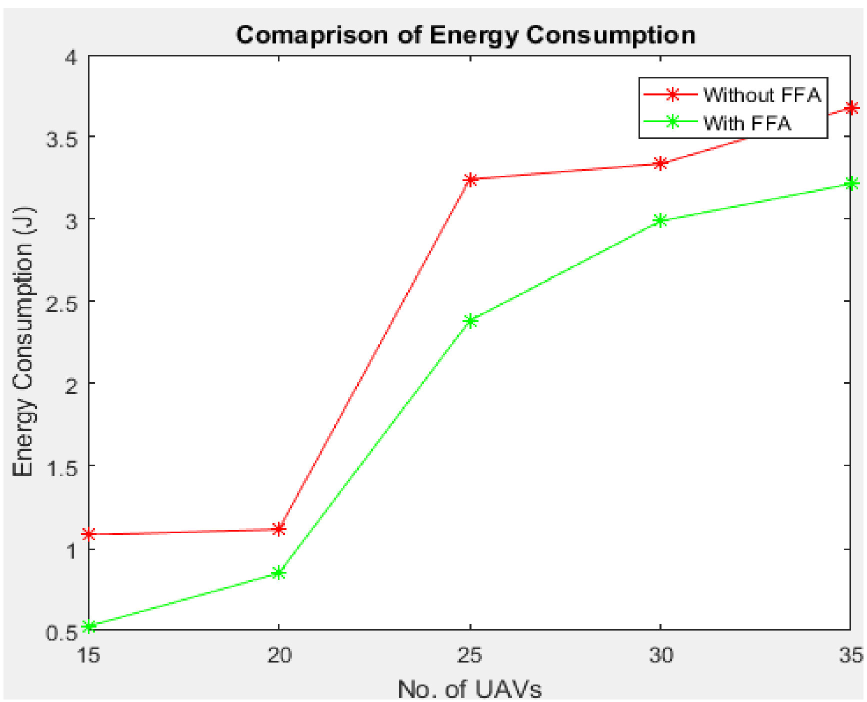

Figure 5 Energy consumption vs no of UAVs in grid size 3000×3000m^2

Cluster lifetime

Cluster lifetime is the time of cluster from its formation to disposition that is its selection as a cluster head till it reaches its threshold and selection of new cluster head depending on fitness function of cluster members that completes the requirement of cluster management. Shorter cluster lifetime also increases the energy consumption, computation overhead in cluster that increases the load of clustering algorithm that it needs to be executed repeatedly. Number of UAVs also affects the network by changing topology of network, for reliability of network less number of nodes as possible should be considered. Cluster lifetime is an

important parameter of clustering it should longer and our proposed algorithm works efficiently and better than GSO in cluster lifetime management in Fig 6 and 7.

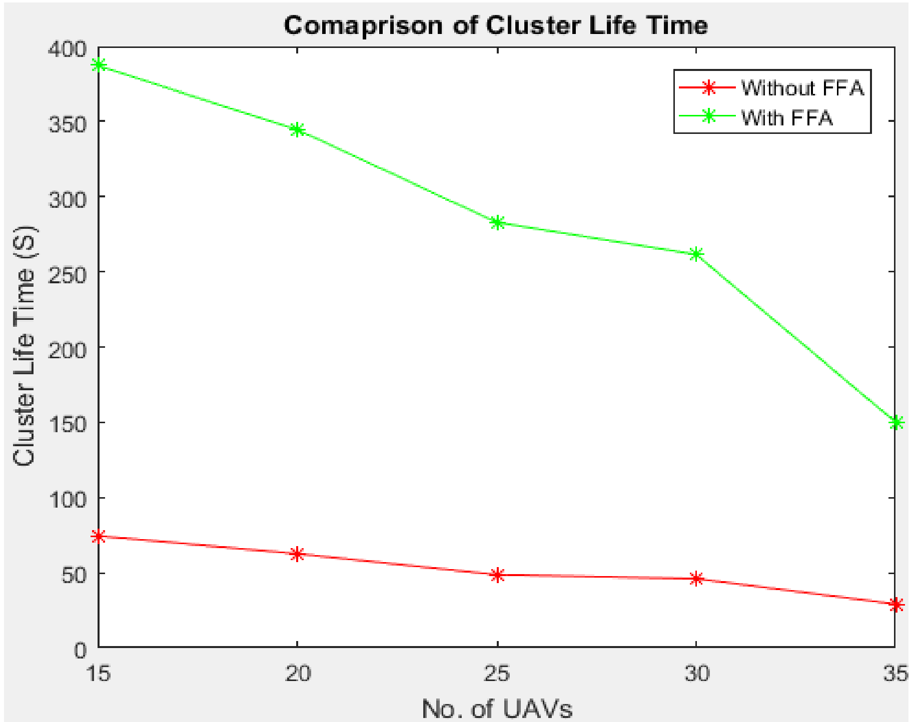

Figure 6 Cluster lifetime vs no of UAVs in grid size 1000×1000m^2

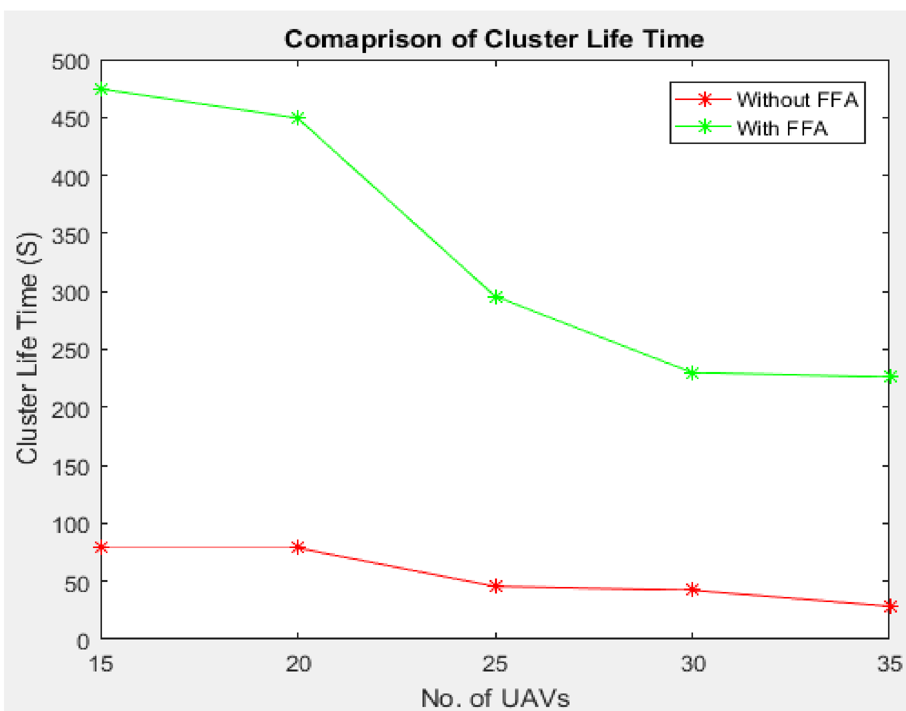

Figure 7 Cluster lifetime vs no of UAVs in grid size 3000×3000m^2

Probability of delivery success

Probability of successfully delivering data packets from transmitting to receiving end based on of average number of hops per packet. With increase in number of UAV resultant increase in network density, decrease in packet drop ratio and increase in probability of delivery success. It can be noted that proposed algorithm in Fig 8 and 9 shows better results than GSO.

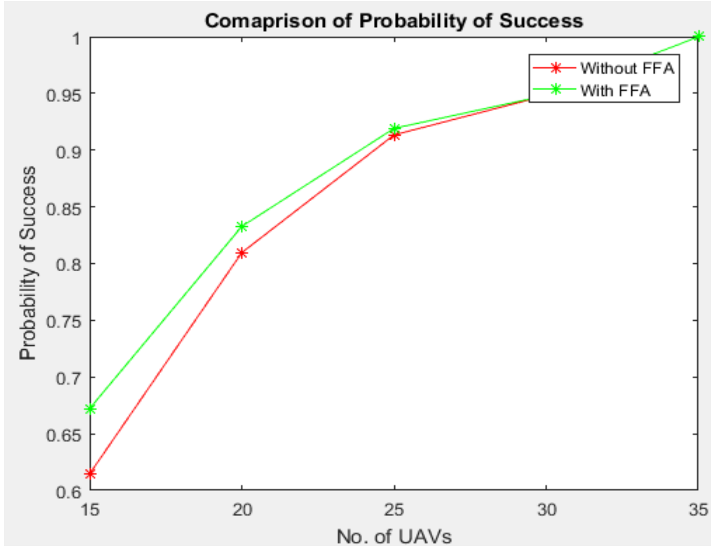

Figure 8 Probability of successful delivery vs no. of UAVs in grid size 1000×1000m^2

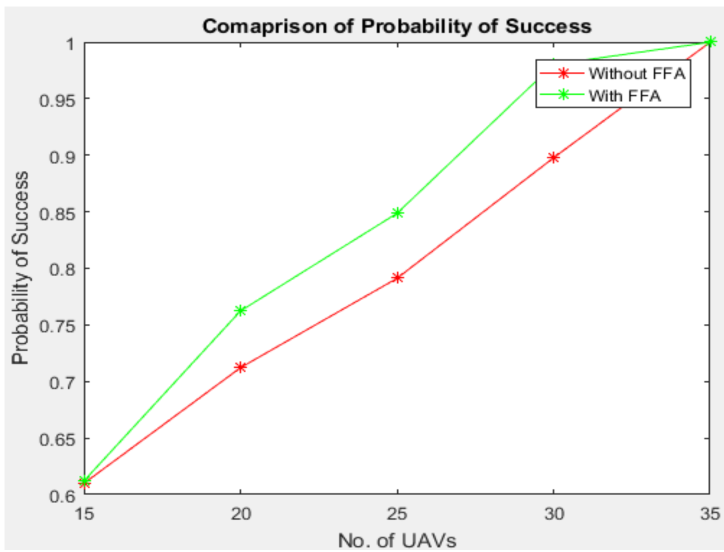

Figure 9 Probability of successful delivery vs no. of UAVs in grid size 3000×3000m^2

4. CONCLUSION & FUTURE SCOPE

In this paper, we have discussed the UAV and its applications, network of UAV called FANET,. affect on communication due to and its changing topology for the solution of this problem Proposed clustering using SOCS hybridized with k-means algorithm for cluster management which involves selection of cluster head on basis of fitness function and connectivity with ground control station for routing and efficient communication between UAVs other firefly optimization with Artificial neural network is proposed. Then, result is evaluated in terms of cluster building time, energy consumption, cluster lifetime, probability of delivery success. In future scope of this paper, saved routing path can be used for trust management for transmitting confidential information.

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